Santa Clara University

DEPARTMENT of COMPUTER ENGINEERING

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ENTITLED

Mapping Robot Utilizing Amigobots

BE ACCEPTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE

DEGREE OF

BACHELOR OF SCIENCE IN COMPUTER ENGINEERING

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Mapping Robot Utilizing Amigobots

by

Bernard Farrales and Francis Chan

SENIOR DESIGN PROJECT REPORT

Submitted in partial fulfillment of the requirements
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Santa Clara University

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Mapping Robot with Activemedia's Amigobot

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ABSTRACT

Robots in today's world are utilized in environments that are just too dangerous for human intervention. They provide us eyes, ears, and touch to places we usually see unfit. Our objective is to provide a cognitive sense of mapping memory to assist in the explorative endeavors of these environments with the use of sonar technology. In this paper we utilize sonar technology to map a room of unknown dimensions along with autonomous navigational capabilities. Our experiments show that sonar data can be very inaccurate at very close and far ranges along with slight angles. We counteract these inaccuracies with the use of a Gaussian filter and distance filters. We identified that the sonar works best at a certain threshold usually ranging from 1200-1500 centimeters which we have reflected to our filter. This threshold also changes when the robot is exposed to different environments. Consequently to make sonar more reliable dynamic thresholds in combination with a wall following algorithm will keep our values as accurate as possible and give us a better view of the real world.

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Chapter 1. INTRODUCTION

Our main goal of this project is to allow a robot equipped with sonar sensors to map a room with unknown dimensions at an unknown origin.

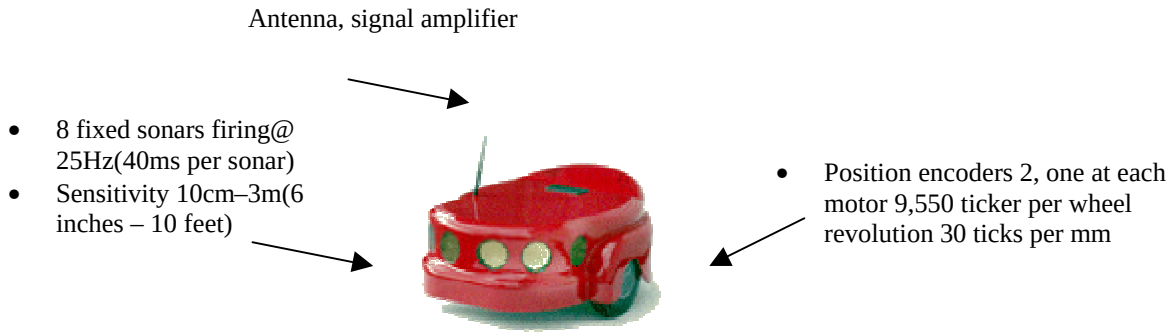
1.1 Background

The primary function of our robot is for us to be able to drop our robot off anywhere in an unknown room and allow it to navigate throughout the room while incrementally mapping its pinged sonar values to a 2D plane. The bundled Activemedia software already provides us with a wide array of functions for our robot; however it lacks the robust autonomy to actually map an unknown area.

Main Objectives

- **Development of an interface between our mapping software and the robot.**
- **Development of an GUI interface and graphical mapping program**
- **Development of an algorithm that will be able to filter false sonar readings to our database.**

Robot Diagram(1-1): ***Activemedia Amigobots©***


Antenna, signal amplifier
8 fixed sonars firing@ 25Hz(40ms per sonar)
Sensitivity 10cm–3m(6 inches – 10 feet)
Position encoders 2, one at each motor 9,550 ticker per wheel revolution 30 ticks per mm

1.2 Project Goals

Design

Our main goal here is to do enough research to be able to develop a simple yet robust algorithm. We attempt to take software engineers approach to this problem, with little or no knowledge of sonar filtration or localization algorithms, we find ourselves jumping into unknown territory. It is imperative that our design be as flawless as possible or else we will be paying dearly in our testing phase trying to work out the bugs.

Implementation

Activemedia has provided an extensive library of access functions to the robot known as "Aria" which is written in C++. We decided to write the rest of the mapping algorithm, GUI, and database all in C++ as well to ensure compatibility. Another important concern for us during the implementation phase is whether will have sufficient time to debug the whole robot to an acceptable range of precision. It's not known to us yet at how accurate the sonar will and how much error we will attain from the inaccurate nature of sonar technology.

Testing

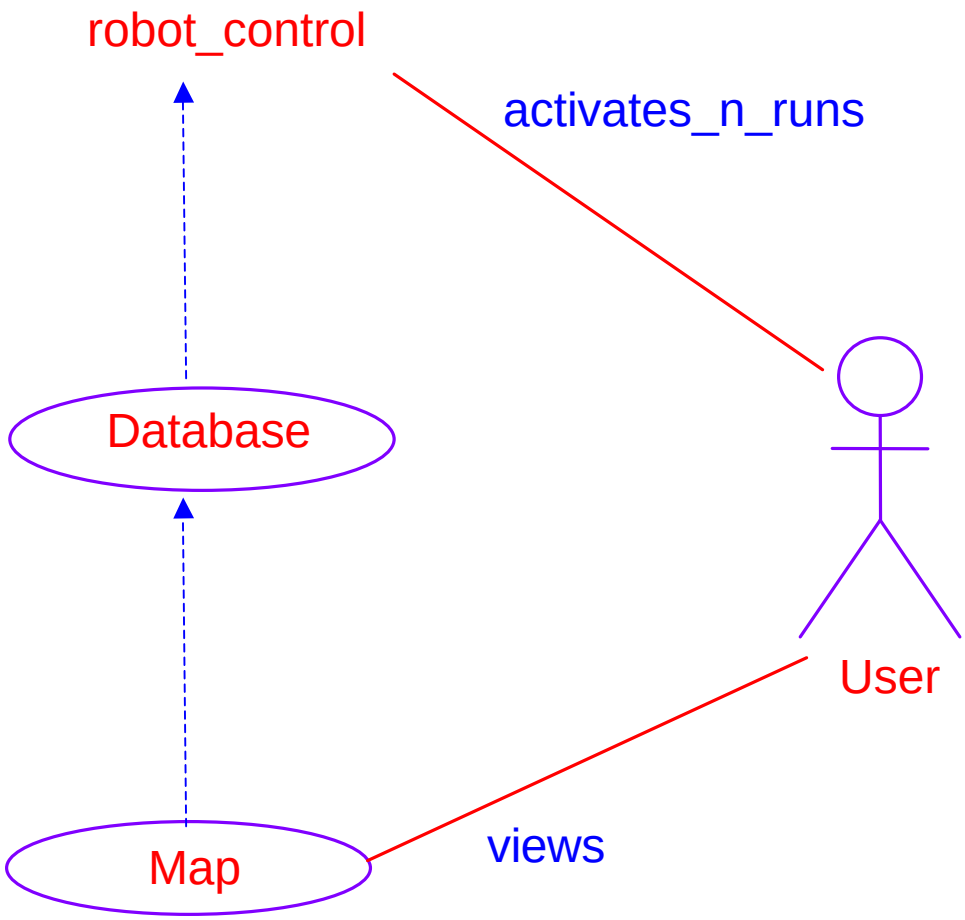
Different environments may give us very different results, i.e. using sonar in a room full of loud subwoofers and acoustics will render our readings useless. We will have to provide enough diversity in our testing phase to ensure that all the algorithms are working efficiently and give us accurate map values. Finding an area where we will able to conduct these experiments accurately.

1.3 Contributions

We would like to thank the Santa Clara University Robotics department for the donation of the amigobot, pc's, and lab rooms to make this project possible.

CHAPTER 2 SYSTEM OVERVIEW

2.1 Use Case(2-1)



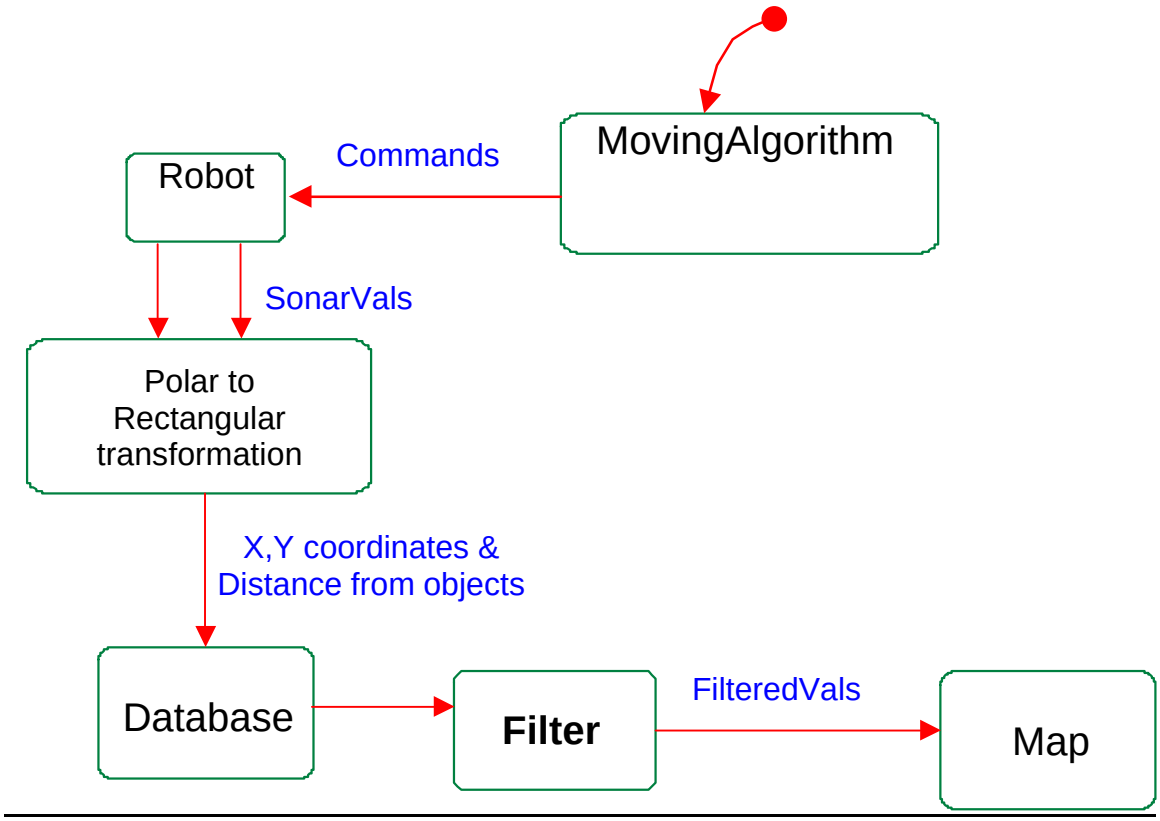
The “Robot Control” will hold our mapping and movement algorithms that we programmed into the robot all the user has to do is activate and run the robot. The user will interact with is the database, which will contain a flat file of x and y values. The display map will have a visible GUI interface that will graphically display the values in the database in a visual topological grid.

-User Activates and runs the robot

-User has the option to analyze raw data values in database

-User can visually analyze the map via gui

2.2 Conceptual Model(2-2)

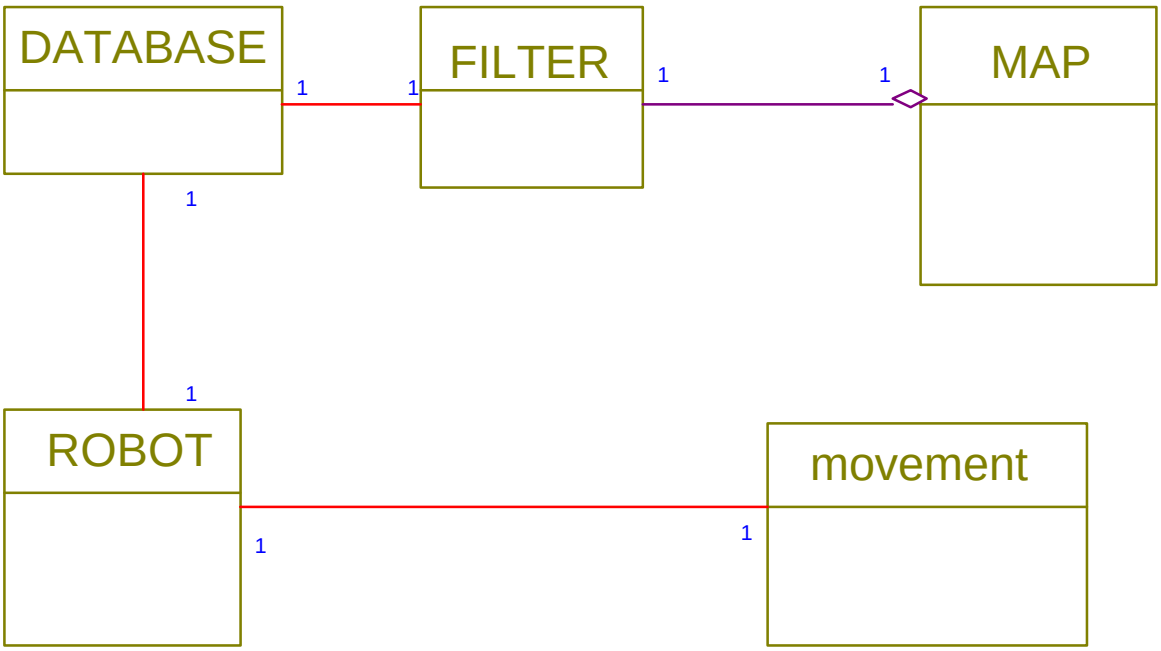


2.3. List of Requirements

- Sonar/Odometer Equipped robot provided by Activemedia's Amigobot
- PC w/ 300Mhz or better w/ open serial port
- Software Interface to robot MCU
- Closed controlled static environment to be mapped
- C++ compiler

CHAPTER 3 SOFTWARE

3.1 Architectural Diagram(3-1)



3.2 Class Descriptions

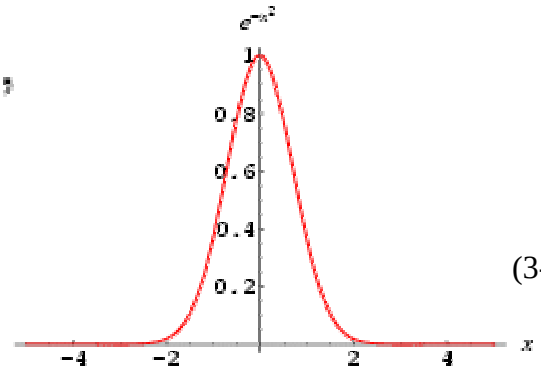
Database

consists of a 2 dimensional array of (x,y) coordinates. Each value is tagged along with a probability value determined by our filter.

Filter

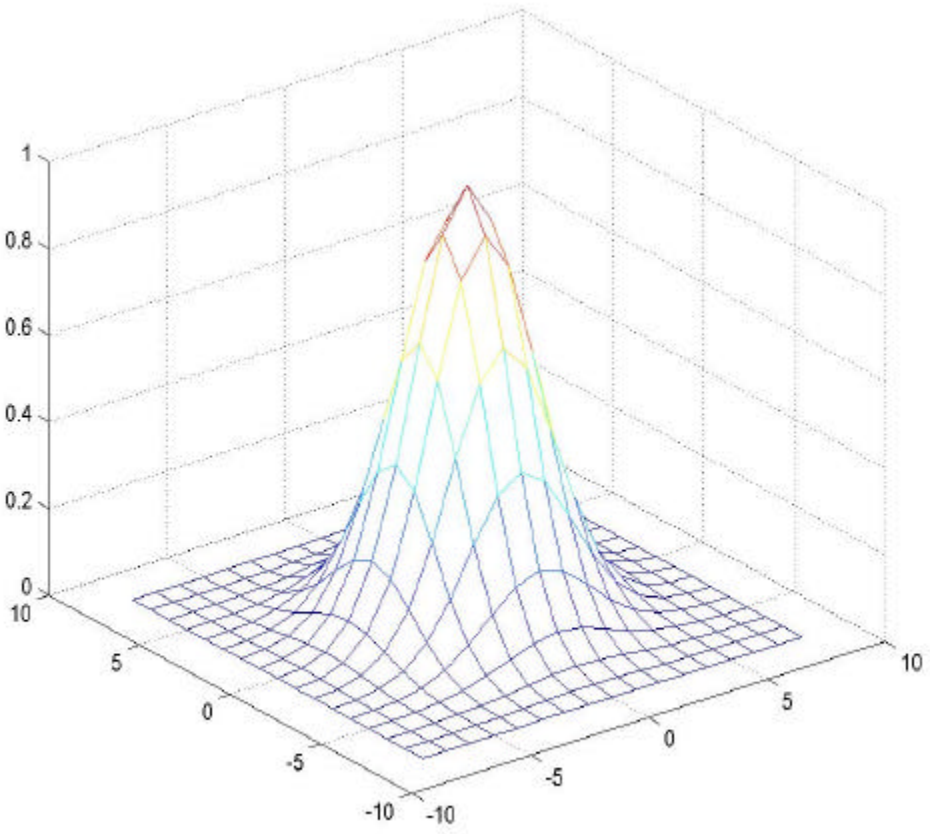
The filter is based upon two functions, the first one being a simple distance filter given to us by the limitations by the sonar. Specifically the sonar will not register if it is too close or too far from an object and we have accommodated this discrepancy when ever we take readings with a threshold. The second filter we have implemented is a *Gaussian function*:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(x-\mu)^2/2\sigma^2},$$



(3-2)

After extensive testing of the robots sonar we pinpointed a value in which we accumulated the best readings and used that as our peak. Hence whenever we took a value the closer to our peak a higher probability value was tagged onto the sonar reading to be stored into the database. The end result is a valley of sonar readings to be stored into database as shown in the next diagram.



(3-3)

Hence the end result will be a map consisting of valleys in which we can decide exactly how much of the “valley” we want to show on the map which will translates to a higher filtered map the higher probability we choose to use, vice versa.

Map

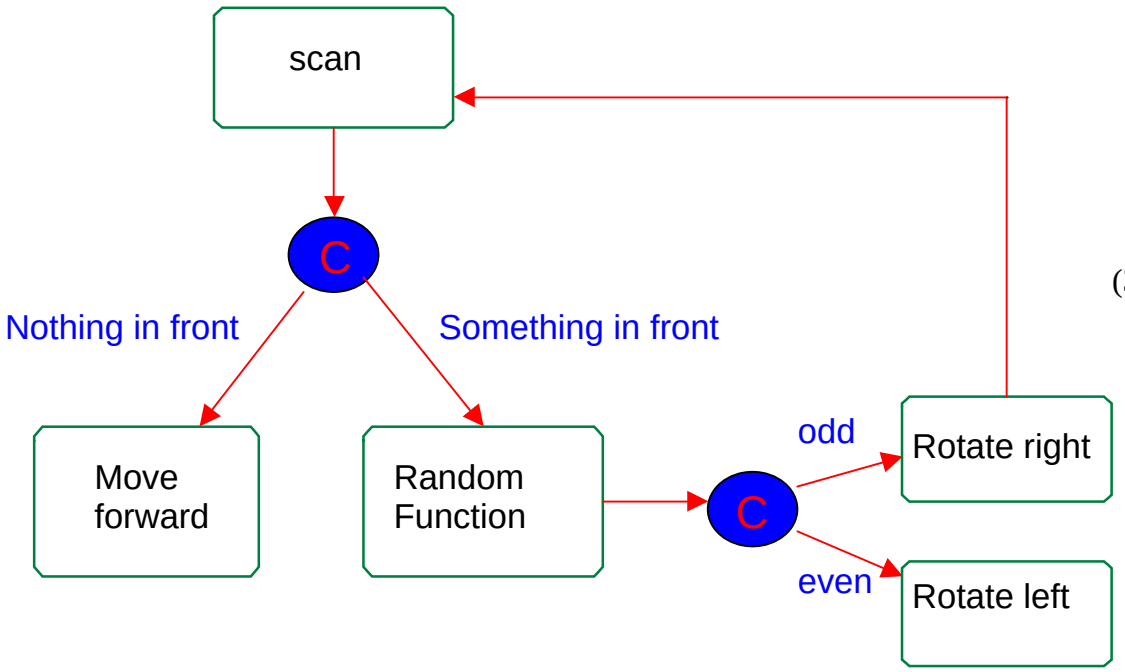
takes in the filtered values from the database and generates a GUI of a map.

Robot

Command control for our robot which receive and deliver commands sent via wireless modem.

Movement

Our movement algorithm consists of a wander function as described in the following state chart.



(3-4)

3.3 Technologies Used

- **Aria**
  - Library functions for the amigobot provided by activemedia that allows us to communicate with the robot.

- **Activemedia software suite**
  - Provides us interface to programming and observing the robot.
- **Rhapsody**
  - C++ UML program used to construct our OMDs and statechart diagrams.

- **Microsoft Visual C++**
  - Used to develop our code and run our robot.

- ***Amigobots© by Activemedia Robotics***
  - Robotic unit
  - Specifications included on next page

3.4 Robot Specifications

Mapping Amigobot SPEC

- Physical Characterisitics
    - Robot measurements: 33cm X 28cm X 13 cm
    - Body clearance: 3 cm
    - Weight: 3.6 Kg
    - Payload: 1 Kg
- Construction
    - Body: Molded polycrb
    - Chassis: 1.6mm fab alum
    - Assembly: Allen hex screws (metric)
- Power
    - 12V lead-acid
    - Charge 24.2 watt-hr
    - Run time: 3+ hours
    - Recharge time (trickle) 12 hrs
    - Recharge time (hi-cap) 4 hours
- Mobility
    - Drive wheels: 2 solid rubber, with caster balance
    - Wheel diameter: 10 cm
    - Wheel width: 3cm
    - Steering: Differential
    - Gear ratio: 19.5:1
    - Swing Radius: 33cm
    - Turn Radius: 0 cm
    - Translate speed max: 750mm/sec
    - Rotational speed max: 300 degrees/sec
    - Traversable step max: 1.5 cm
    - Traversable terrain: all wheelchair accessible
- Sensors
    - Fixed sonar:

        - 8 total
            - 4 forward, 2 at rear, 1 at each side
        - Firing rate 25Hz(40 ms per sonar)
        - Sensitivity 10cm – 3meters(6 inches – 10 feet)
            - Note any objects closer than 10 cm are read as 10 cm
        - Problems include external noise and false echoes
        - Limitations: environment must be quiet, flat surfaced, with minimal reflected surfaces surrounding the perimeter
    - Position encoders
        - 2, one at each motor
            - 9,550 ticker per wheel revolution
            - 30 ticks per mm
- Electronics
    - Processor : 20 MHz Hitachi H8
    - Position inputs: 4
    - Sonar inputs: 1x8(multiplexed)
    - Digital I/O: 8-bit logic ports
    - A/D: 4@0-5VDC
    - Digital timer inputs: 6@ 1microsec resolution
    - Comm port: 3 RS-232 serial
    - FLASH: 64 KB uP/1MB external
    - RAM: 16KB uP
- Controls and Ports
    - Main Power: Robot/accessories power ON/OFF
    - Charge: System power/battery recharge
    - Reset: Warm reboot/download
    - Mortors/Test: Motors/download/self-tests
    - Radio: Power and serial
    - Speaker: 8-ohm
    - Serial comm. Ports: 3 x RS232(Control/System/AUX)

CHAPTER 4 TESTING

4.1 Test plan

Sonar

Our first step in testing the robot is to test out its sonar systems and the accuracy of them. For this we conducted 2 different tests:

I. Comparative Tests of the Sonar data to actual distance of the robot to the wall.

II. Comparative tests of the Sonar data at different angles to a wall to the actual distance from the sonar sensor to the wall itself

III. Comparative tests in different locations in a room with e.g. corners, noisy rooms, and long halls.

IV. Next series of tests will repeat steps I-III with the use of the filters.

Movement/Mapping

Our second step was to test out our movement algorithm once we had our sonar sensor data working correctly. The progression of the testing attempted to start with a simple environment to a highly complex environment so that we can specify the limitations of the robot, no matter what the case.

I. Mapping of a square enclosed room with 4 walls
II. Mapping of a square enclosed room with a movement algorithm that turns left only
III. Mapping of a square enclosed room with a movement algorithm which turns randomly
IV. Mapping of a square enclosed room with wander function with an obstacle

V. Mapping of a hallway using the wander function starting from parallel to the walls
VI. Mapping of a hallway using the wander function starting from a random angle to the wall.

4.2 Test Results

Sonar

Extensive testing has concluded a few parameters that our design should try to follow. First of all our best readings came from when the sonar sensor is perpendicular to the wall it was pinging off of. Slight change in the angles however would throw our readings off especially at very close and far ranges. Corners also served as a problem for the sonar as readings that came from them usually read either very close or very far beyond the actual physical object.

One thing we did notice is that readings from a 120cm – 150cm on average seemed to give us the best readings. We used values within our threshold Gaussian function as the peak point. The closer the sonar readings were to these distances the more we can believe that they were actually there. Of course our values in which were below 50cm and beyond 2000cm were automatically thrown out of our database even though they were read in. Further results of our filter in action will be more extensively shown below.

Different materials, from hard wood walls to dampened dry wall seemed to give us both the same type of readings consistently. Even the poor readings we got in other test cases were received on different mediums. For corners we realize that it just simply the downfall of sonar technology and that certain levels of inaccuracy can be expected.

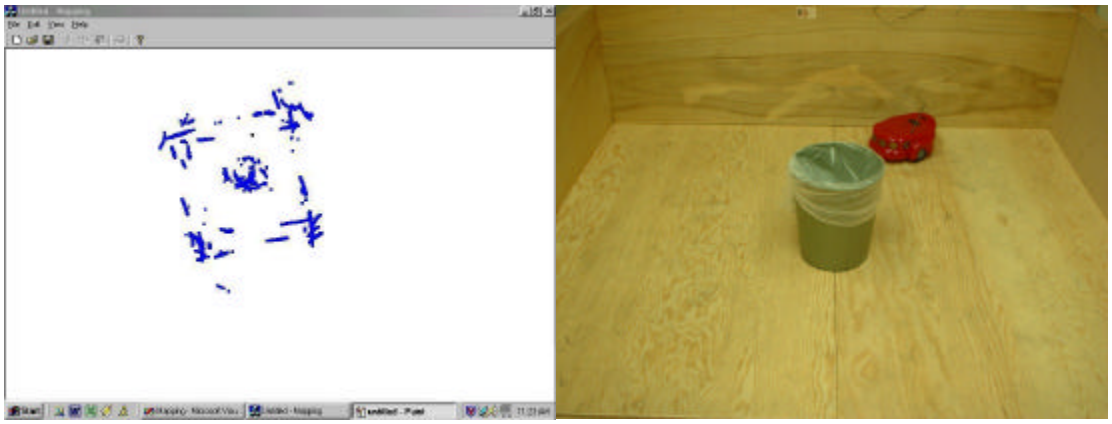
Movement and Mapping

Initial results with our moving algorithm started with a simple left turn only algorithm. We quickly changed this when we noticed that the robot would keep moving in the same circle around our closed control environment. The results of the continuous circles would

cause our map to drift counter clockwise because of the continuous wheel slippage in one direction. We remedied this problem by implementing a random turning function where every ten iterations the robot would decide randomly to turn left or right. This gave us map in which ensures that all parts of the physical world are probed. Our wander function is somewhat similar to the simulation wander function found in the Activemedia suite. We analyzed that the robot would only move when one of the front sonars and side sonars were reading open space in front of it. Tuning the velocity of the robot turns and movements was also another challenge. Fast abrupt movements would cause the robot to slip and corrupt more of our readings.

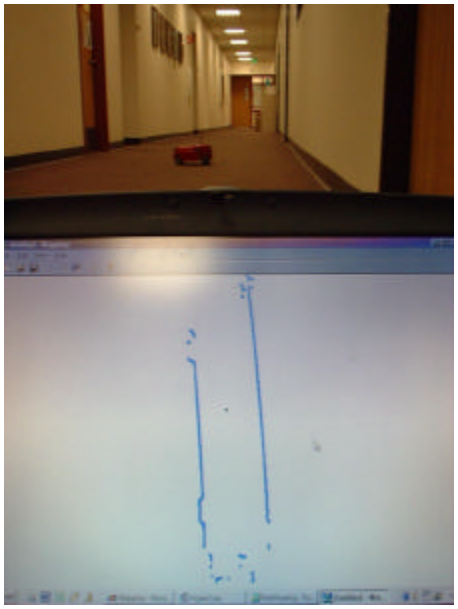
Secondly the corner distribution was unavoidably bad in most cases with filtering. It is also important to note that the high filtered values cleaned up the very inaccurate readings from our sonar much better than the low filtered did. Echoes that bounced around 2-3 different walls back to our sonar usually gave us readings further than what the real world was, these values however were filtered out and the corners were cleaned up as you can see in the following pictures that display the same room with different grades of filtering.

Thirdly our mapping function in conjunction with our obstacle avoidance algorithm showed promising results as shown below.



(4-1)

As you can see the environment with an oblong object which the sonar has a very hard time reading because of its round shape is mapped fairly well considering its structure. The four walls are defined in this map using medium filtering. Another important aspect to this filtering is that it can tuned in many ways. The sensitivity of the sonar itself is adjustable so that better readings of long flat objects can be taken accurately while smaller objects are more likely missed. The opposite is true when the sensitivity is turned up. Once the map has been attained the filter can be turned up or down in order to optimize the map of the real world.



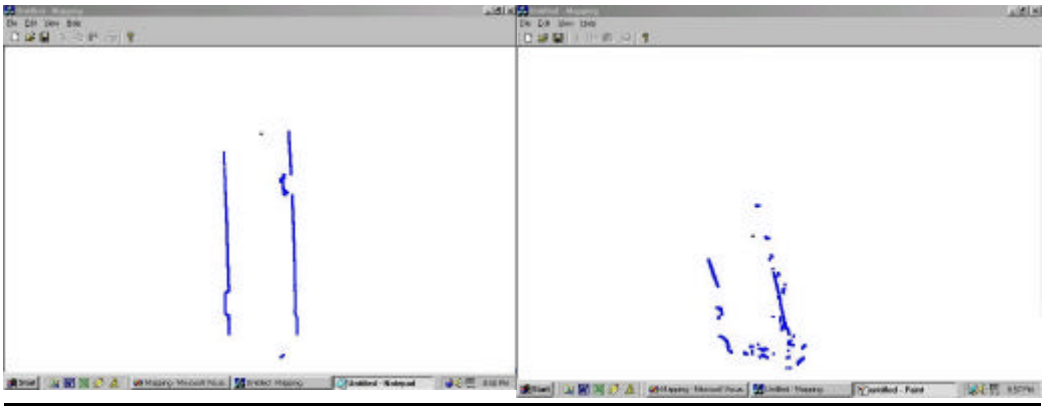
Our long hallway mapping test went very well whenever we started our robot at the ideal perpendicular position as shown below.

This test was taking over a 5 minutes time span down a long hall found in the engineering dept. The walls were constructed of drywall and as you can observe the walls are very accurately mapped along with the doorways.

However this won't be the case all the time when the robot is placed in a random environment so also duplicated this experiment with the robot at a biased angle with a medium fitler.

(4-2)

However this won't be the case all the time when the robot is placed in a random environment so also duplicated this experiment with the robot at a biased angle with a medium filter.

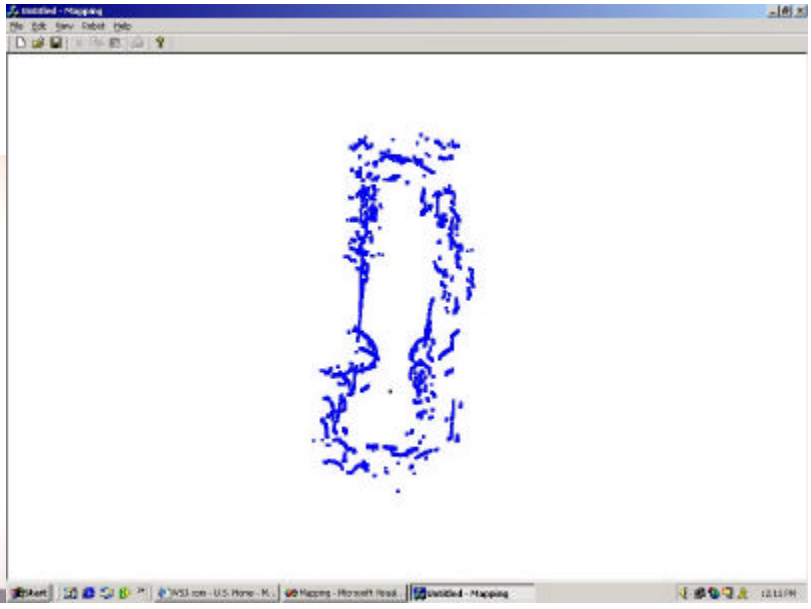


(4-3)

As you can see the smallest variation in angle can throw off the values somewhat. Our results however turned out fairly decent as both the doorway and the walls were mapping with decent precision.

Our last test was conducted in a random environment where no artificial biases could be presented in favor of the sonar. The results are as follows:

(4-4)



(4-5)

With medium filtering the results we retrieved were very promising. Because of large number of oblong objects and loose material, i.e. electrical wire found on the ground, we were expecting very poor values. But in fact the robot was able to scan the garbage can found on the left, which is the round half moon values taken on the left side of the wall.

Many of the loose wiring found at the end of the room was scanned fairly accurately and the robot had no problems navigating through this environment.

CHAPTER 5 USER MANUAL

SOFTWARE INSTALLATION 1

Step 1: Install Aria Active-Media Suite and Visual C++ on your computer.

Step 2: In Visual C++, create a new MFC Application project titled “Mapping” using the Wizard and the default settings.

Step 3: Link the new project to the Aria libraries. (See Sample Aria projects for information on how to link libraries)

Step 4: Download myRobot.cpp and myRobot.h and import them into the project workspace.

Step 5: Replace MappingView.cpp and MappingView.h with the updated version.

Step 6: Compile and Run the code.

QUICK INSTALLATION

Step 1: Create a new Folder and copy the Mapping Directory into it

Step 2: Install Aria Active-Media Suite and copy the libraries into the newly created folder.

Step 3: Open up the Mapping Workspace using Visual C++

Step 4: Compile and Run the code.

CONNECTING AND DISCONNECTING FROM THE ROBOT:

You should automatically be connected to the robot upon execution of the program. If by chance you are not, click on the Robot menu and select "Connect".

To disconnect from the robot simply close the program or select "Disconnect" from the Robot menu.

CONTROLLING THE ROBOT:

up arrow - move forward
down arrow - move back
left arrow - rotate counter-clockwise 10 degrees
right arrow - rotate clockwise 10 degrees
enter - (Scan) sends the sonar data to the database
spacebar - draws a map using values from the database
delete - clears the data in the database and clears the screen

AUTOMATED FUNCTIONS:

Wander (double left-click) - Wanders around the room while scanning and avoiding nearby objects and continually updating the map. Double left-click again to pause and resume.

Spin and Scan (double right-click) - Rotates 360 degrees counter-clockwise while taking scans every 10 degrees.

CHAPTER 6 Other Issues

1.Social

Social impact of our project would allow society to venture into hostile environments which would be normally accessible for human interaction. For example unsafe buildings could be probed by our robot for safe paths to travel. Hazmat teams could be able to search buildings for obstacles and safe paths to traverse in order to find precious cargo. Essentially it will allow society an artificial cognitive sense of mapping as robots have allowed us to extend our senses without putting ourselves in immediate harms way.

2.Political

Our project has no political aspect what so ever.

3.Economic

Our project replicated a costly piece of software that is sold by Activemedia and could be easily further developed to be competitively held up against Activemedia's mapping software. In a sense we are on the road to stimulate the market for robotics software.

4.Health

Our project has not direct relation to any current health issues.

5.Safety

Our project is relatively safe. The mapping software allows people to map environments and get a better idea what their physical world looks like without them getting out of their chair.

6.Manufacturability

The Mapping robot software can be easily ported to any amigobot making it very accessible to anyone who owns both an amigobot and the activemedia software bundle.

Manufacturability is only limited to how many robots Activemedia produces per year and different prices.

7.Sustainability

We developed the software to be very easily used and maintained. Documented comments and simple user interface will give the user a better conceptual idea of how our program works allowing the user to make new changes to the design if needed.

8.Environmental impact

Our product does not have an direct impact on the environment although it important to note that most of the materials on our robot, except the power source, are recyclable.

9.Usability

As noted the design of the robot interface was for simplicity and ease of use. Basically all the user needs to do is push one button after uploading the code.

10.Lifelong Learning

The design on this robot could be developed in many other ways allowing those who will take on this project in the future to learn even more about robotics and the way we replicate our human senses to the artificial world. Multiple threading with other robots and further development on ways to filter out sonar data are just a few more things we could learn more about with further implementation.

11.Compassion

Our project, if developed further would be able to help the blind navigate through environments without the use of a walking stick or walking dog. Our robot could actually serve as a type of “seeing eye dog” that could be able to translate the maps into brail as well.

CHAPTER 7 CONCLUSION

7.1. Summary of Work

After further testing the flaws of our code were worked out so that our final working product is able to move, filter, and map. The movement algorithm proved to be very reliable as our incident of impact to any obstacles in a room was minimized to zero after we readjusted the turning algorithm. The filter is works well but needs to be readjusted depending on what kind of environment the robot is mapping. The user will be able to choose a best fit map by turning the filter up or down. The visual mapping part of our project works well and maps the data values stored in our database straight to the user with no problems.

7.2. Project Challenges and Future Implementation

Some of the challenges of our project included the limitations of sonar technology as it doesn't operate very well in certain environments especially that when the object to be read is too far, too close, or too high of an angle. Obstacle avoidance was a challenge to find the exact turn radius interval to allow the robot to not hit a blind spot found within the sonar. Whenever the robot did make contact with a wall we usually experienced wheel slippage as well which corrupted our sonar values. It is also important to note that the velocity of forward movement and turning should be reasonably low as high velocities would cause the robot to jerk when it moved causing more wheel slippage in the process. Finding the correct threshold filter for our test environment was challenging as well. Design aspects allow us to change this to suit what ever environment we may run into decided upon the user.

Future implementation would include the ability to keep the sonar perpendicular to the wall to provide us the best values possible from our sonar. As we analyzed earlier we received the best readings whenever the sonar is perpendicular to an object. Dynamic thresholding would be another aspect of future design as we hope the robot would be able to determine the best degree of filtering by assessing the type of room it is in then optimizing the filter to get the best fit map. Localization would also be ideally implemented by fusing the odometer sensor along with the sonar to compare and contrast

the previous taken values with the current values to make a final determination that the point it is at actually is the point in reality.

7.3. “The Big Picture”

Overall we would like to see this project continued and improved with years to come. Hopefully even combine with other projects such as the formation robots. Further development would allow further research into the optimization of sonar technology and perhaps a better way to implement it in industry. We were fortunate enough to be able have the accessibility to these great learning tools, the amigobots, and hope others in the future will take full advantage of these robots in years to come.

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Appendix

Appendix A.1 MappingView.cpp:

```
// MappingView.cpp : implementation of the CMappingView class
//

#include "stdafx.h"
#include "Mapping.h"
#include "MappingDoc.h"
#include "MappingView.h"
#include <math.h>
#include <process.h>
#include <windows.h>

#ifdef _DEBUG
#define new DEBUG_NEW
#undef THIS_FILE
static char THIS_FILE[] = __FILE__;
#endif

myRobot red;

/////////////////////////////////////////////////////////////////////////////
// CMappingView

IMPLEMENT_DYNCREATE(CMappingView, CView)

BEGIN_MESSAGE_MAP(CMappingView, CView)
      //{{AFX_MSG_MAP(CMappingView)
      ON_WM_LBUTTONDBLCLK()
      ON_WM_RBUTTONDBLCLK()
      ON_WM_KEYDOWN()
      ON_WM_KEYUP()
```

```
	ON_MESSAGE(WM_SCANDRAW, OnScanDraw)
	ON_COMMAND(ID_ROBOT_CONNECT, OnRobotConnect)
	ON_COMMAND(ID_ROBOT_DISCONNECT, OnRobotDisconnect)
	//}}AFX_MSG_MAP
END_MESSAGE_MAP()

/////////////////////////////////////////////////////////////////////////////
// CMappingView construction/destruction

CMappingView::CMappingView()
{
	red.connect();

	filter = 0.0;		//minimum probability in order for coordinate to be valid (drawn)
	mean = 800;	//mean for the gaussian function
	stdev = 200;		//standard deviation for the gaussian function
	PI = 3.14159265;
	var = stdev*stdev;

	xmax = 1020;		//width of the screen in pixels
	ymax = 675;	//height of the screen in pixels

	size = 2;	//size of the dot to be drawn at coordinate x,y

	box = 12;	//increase the number to lower the resolution

	xstart = xmax/2;  //x starting position of the robot on the screen (in this case, the center of the x
axis)
	ystart = ymax/2;  //y starting position of the robot on the screen (in this case, the center of the y
axis)
	xpos = xstart;
	ypos = ystart;

	moveThread=0;		//initialize at 0 to indicate no thread is running


	//creates 3 brushes black, blue, and white
	black = new CBrush();
```

```
	black->CreateSolidBrush(RGB(0,0,0));
	blue = new CBrush();
	blue->CreateSolidBrush(RGB(0,0,255));
	white = new CBrush();
	white->CreateSolidBrush(RGB(255,255,255));

	//creates a two-dimensional array of xmax and ymax
	//and initializes the values to 0
	DB = new double * [xmax];
	for(int z=0; z<xmax; z++)
	{
		DB[z] = new double[ymax];
	}
	for(z=0; z<xmax; z++)
		for(int b=0; b<ymax; b++)
			DB[z][b]=0.0;
}

CMappingView::~CMappingView()
{
	if(red.isConnected())
		red.disconnect();
}

BOOL CMappingView::PreCreateWindow(CREATESTRUCT& cs)
{
	return CView::PreCreateWindow(cs);
}

/////////////////////////////////////////////////////////////////////////////
// CMappingView drawing

void CMappingView::OnDraw(CDC* pDC)
{
	CMappingDoc* pDoc = GetDocument();
	ASSERT_VALID(pDoc);
	draw();
}
```

```
/////////////////////////////////////////////////////////////////////////////
// CMappingView diagnostics

#ifdef _DEBUG
void CMappingView::AssertValid() const
{
	CView::AssertValid();
}

void CMappingView::Dump(CDumpContext& dc) const
{
	CView::Dump(dc);
}

CMappingDoc* CMappingView::GetDocument() // non-debug version is inline
{
	ASSERT(m_pDocument->IsKindOf(RUNTIME_CLASS(CMappingDoc)));
	return (CMappingDoc*)m_pDocument;
}
#endif //_DEBUG

/////////////////////////////////////////////////////////////////////////////
// CMappingView message handlers


//Thread consisting of the moving algorithm
UINT Move(LPVOID param)
{
	bool left=true;
	bool turn=false;
	int i=0;
	::PostMessage((HWND)param, WM_SCANDRAW, 0,0);
	while(true)
	{
		while(red.checkFront())
		{
			if(left)
```

```
                        red.rotate(15);
                  else
                        red.rotate(-15);
                  ::PostMessage((HWND)param, WM_SCANDRAW, 0,0);
                  turn=true;
            }
            red.move(10);
            ::PostMessage((HWND)param, WM_SCANDRAW, 0,0);
            if(turn)
            {
                  if(++i >= 10)
                  {
                        if(rand()%2==0)
                              left=true;
                        else
                              left=false;
                        i=0;
                  }
            }
            turn=false;
      }
      return 0;
}

void CMappingView::OnLButtonDblClk(UINT nFlags, CPoint point)
{
      HWND hWnd = GetSafeHwnd();

    if(moveThread==0)
      {
            pThread = AfxBeginThread(Move, hWnd, THREAD_PRIORITY_NORMAL);
            moveThread=1;     //1 = thread running
      }
      else if(moveThread==2)
      {
            pThread->ResumeThread();
            moveThread=1;     //1 = thread running
      }
```

```
	else
	{
		pThread->SuspendThread();
		moveThread=2;	//2 = thread suspended
		red.stop();
	}
	CView::OnLButtonDblClk(nFlags, point);
}

void CMappingView::OnRButtonDblClk(UINT nFlags, CPoint point)
{
	scan();
	draw();
	for(int x=41; x>0; x--)
	{
		red.rotate(10);
		while(!red.turnDone()) { }
		scan();
		draw();
	}
	CView::OnRButtonDblClk(nFlags, point);
}

void CMappingView::draw()
{
	CClientDC dc(this);

	dc.FillRect(CRect(xpos-size,ypos-size,xpos+size,ypos+size),white);

	xpos = red.getX();
	ypos = red.getY();
	xpos = convertx(xpos);
	ypos = converty(ypos);

	dc.FillRect(CRect(xpos-size,ypos-size,xpos+size,ypos+size),black);

	for(int x=0; x < xmax; x++)
	{
```

```
            for(int y=0; y < ymax; y++)
            {
                  if(DB[x][y] > filter)
                  {
                        dc.FillRect(CRect(x-size,y-size,x+size,y+size),blue);
                  }
            }
      }
}

void CMappingView::dataB()
{
      for(int x=0; x < 8 && sonars[x][0]!= 9999 && sonars[x][1]!=9999; x++)
      {
            int pointx = sonars[x][0];
            int pointy = sonars[x][1];
            int length = sonars[x][2];
            double probability = Gauss(length);
            pointx = convertx(pointx);
            pointy = converty(pointy);
            DB[pointx][pointy] += probability;
      }
}

void CMappingView::Decrement(int x, int y)
{
      DB[x][y]-=10;
}

void CMappingView::scan()
{
      int xpos2 = red.getX();
      int ypos2 = red.getY();
      xpos2 = convertx(xpos);
      ypos2 = converty(ypos);
      Decrement(xpos2, ypos2);
      sonars = red.scan();
      dataB();
```

```
}

void CMappingView::OnKeyDown(UINT nChar, UINT nRepCnt, UINT nFlags)
{
	switch(nChar)
	{
		//reset DB (delete)
		case 46:
			reset();
			break;
		//scan and draw (tab)
		case 9:
			scan();
			draw();
			break;
		//draw (spacebar)
		case 32:
			draw();
			break;
		//scan (enter)
		case 13:
			scan();
			break;
		//move forward (up key)
		case 38:
			red.move(10);
			//while(!red.moveDone()){ }
			break;
		//move backwards (down key)
		case 40:
			red.move(-10);
			//while(!red.moveDone()){ }
			break;
		//rotate left (left key)
		case 37:
			red.rotate(10);
			//while(!red.turnDone()) { }
			break;
```

```
            //rotate right (right key)
            case 39:
                  red.rotate(-10);
                  //while(!red.turnDone()) { }
                  break;
      }

      CView::OnKeyDown(nChar, nRepCnt, nFlags);
}


void CMappingView::OnKeyUp(UINT nChar, UINT nRepCnt, UINT nFlags)
{
      red.stop();
      CView::OnKeyUp(nChar, nRepCnt, nFlags);
}

int CMappingView::convertx(int i)
{
      i /= box;
      i += xstart;
      return i;
}

int CMappingView::converty(int i)
{
      i /= -box;
      i += ystart;
      return i;
}

double CMappingView::Gauss(int x)
{
      double A = 1/(stdev*sqrt(2*PI));
      double B = ((x-mean)*(x-mean))/(2*var);
      return 500*A*exp(-B);
}
```

```
void CMappingView::OnScanDraw(WPARAM wParam, LPARAM lParam)
{
	scan();
	draw();
}

void CMappingView::OnRobotConnect()
{
	if(!red.isConnected())
		red.connect();
}

void CMappingView::OnRobotDisconnect()
{
	if(red.isConnected())
		red.disconnect();
}

void CMappingView::reset()
{
	for(int z=0; z<xmax; z++)
		for(int b=0; b<ymax; b++)
			DB[z][b]=0.0;
	clearScreen();
}

void CMappingView::clearScreen()
{
	CClientDC dc(this);
	dc.FillRect(CRect(0,0,xmax,ymax),white);
}
```

Appendix A.2 MappingView.h:

```
// MappingView.h : interface of the CMappingView class
//
/////////////////////////////////////////////////////////////////////////////

#include "myRobot.h"

#if !defined(AFX_MAPPINGVIEW_H__92E42C4C_5421_11D7_9B52_00E0988A2243__INCLUDED_)
#define AFX_MAPPINGVIEW_H__92E42C4C_5421_11D7_9B52_00E0988A2243__INCLUDED_

#if _MSC_VER > 1000
#pragma once
#endif // _MSC_VER > 1000

const WM_SCANDRAW = WM_USER + 100;

class CMappingView : public CView
{
protected: // create from serialization only
      CMappingView();
      DECLARE_DYNCREATE(CMappingView);

      double ** DB;
      int xmax, ymax, xstart, ystart, size, xpos, ypos, box;
      double ** sonars;
      double mean, stdev, PI, var, filter;
      CWinThread* pThread;
      int moveThread;
      CBrush * black, * blue, * white;

// Attributes
public:
      CMappingDoc* GetDocument();

// Operations
public:
```

```
// Overrides
      // ClassWizard generated virtual function overrides
      //{{AFX_VIRTUAL(CMappingView)
      public:
      virtual void OnDraw(CDC* pDC);  // overridden to draw this view
      virtual BOOL PreCreateWindow(CREATESTRUCT& cs);
      protected:
      //}}AFX_VIRTUAL

// Implementation
public:
      virtual ~CMappingView();
#ifdef _DEBUG
      virtual void AssertValid() const;
      virtual void Dump(CDumpContext& dc) const;
#endif

protected:
      void scan();                              //retrieves the position of the robot, decrements that
position
                                          //in the database, and passes the sonar data to the database
      void dataB();                             //increments the coordinates of the database
                                          //depending on the returned value from the gaussian function
      void draw();                              //draws points depending on the values in the database
      int convertx(int i);                      //converts the x value to be stored
      int converty(int i);                      //converts the y value to be stored
      double Gauss(int x);                      //returns a value between 0 and 1 depending on
                                          //the values x, mean, and stdev
      void Decrement(int x, int y);             //decrements the value of the coordinates x,y
      void reset();                             //sets all values in the database to 0
      void clearScreen();                       //clears the screen

// Generated message map functions
protected:
      //{{AFX_MSG(CMappingView)
      afx_msg void OnLButtonDblClk(UINT nFlags, CPoint point);
      afx_msg void OnRButtonDblClk(UINT nFlags, CPoint point);
      afx_msg void OnKeyDown(UINT nChar, UINT nRepCnt, UINT nFlags);
```

```
	afx_msg void OnKeyUp(UINT nChar, UINT nRepCnt, UINT nFlags);
	afx_msg void OnRobotConnect();
	afx_msg void OnRobotDisconnect();
	afx_msg void OnScanDraw(WPARAM wParam, LPARAM lParam);            //user-created message to execute
                                                          //scan and draw during a thread
	//}}AFX_MSG
	DECLARE_MESSAGE_MAP()
};

#ifndef _DEBUG  // debug version in MappingView.cpp
inline CMappingDoc* CMappingView::GetDocument()
   { return (CMappingDoc*)m_pDocument; }
#endif

//////////////////////////////////////////////////////////////////////////{{AFX_INSERT_LOCATION}}
// Microsoft Visual C++ will insert additional declarations immediately before the previous line.

#endif // !defined(AFX_MAPPINGVIEW_H__92E42C4C_5421_11D7_9B52_00E0988A2243__INCLUDED_)
```

Appendix A.3 MyRobot.cpp

```
// myRobot.cpp: implementation of the myRobot class.
//
//////////////////////////////////////////////////////////////////////

#include "stdafx.h"
#include "Mapping.h"
#include "myRobot.h"
#include "Aria.h"
#include <fstream.h>

#ifdef _DEBUG
#undef THIS_FILE
static char THIS_FILE[]=__FILE__;
#define new DEBUG_NEW
#endif

//////////////////////////////////////////////////////////////////////
// Construction/Destruction
//////////////////////////////////////////////////////////////////////

ArRobot robot;
ArSerialConnection serConn;
ArSonarDevice sonar;
ArKeyHandler keyHandler;
double vel = 30;
double rotVel = 10;
int minDistance = 350;

myRobot::myRobot(){ }

myRobot::~myRobot(){}

void myRobot::move(int distance)
{
      robot.setVel(vel);
      robot.move(distance);
```

```
	while(!robot.isMoveDone()){ }
}

void myRobot::rotate(int theta)
{
	robot.setRotVel(rotVel);
	robot.setDeltaHeading(theta);
	while(!robot.isHeadingDone()){ }
}

double ** myRobot::scan(void)
{
	int z, cursor=0;
	int y = robot.getNumSonar();
	double ** sonars = new double * [y];
	for(z=0; z<y; z++)
	{
		sonars[z] = new double[3];
	}
	for(z=0; z<y; z++)
		for(int b=0; b<3; b++)
			sonars[z][b]=9999;

	for(z=0; z<y ;z++)
	{

		//retrieves the position and angle of a specified sonar
		double distance,theta;
		int x,y;
		switch(z)
		{
			case 0:
				x=-105;
				y=73;
				theta=3.14159;
				break;
			case 1:
				x=-78;
```

```
                y=130;
                theta=2.33874;
                break;
        case 2:
                x=-30;
                y=154;
                theta=1.78024;
                break;
        case 3:
                x=30;
                y=154;
                theta=1.36136;
                break;
        case 4:
                x=78;
                y=130;
                theta=0.80285;
                break;
        case 5:
                x=105;
                y=73;
                theta=0.00;
                break;
        case 6:
                x=60;
                y=-146;
                theta=5.340708;
                break;
        case 7:
                x=-60;
                y=-146;
                theta=4.084070;
                break;
}
distance=robot.getSonarRange(z);

//adds sonar data only if the distance is between 300 and 1500
if(distance > 300 && distance < 1500)
```

```
            {
                  theta = theta + robot.getTh() * 3.14159 / 180;
                  x=(-1* robot.getY()) + x + distance * cos(theta);
                  y=robot.getX() + y + distance * sin(theta);
                  sonars[cursor][0]=x;
                  sonars[cursor][1]=y;
                  sonars[cursor][2]=distance;
                  cursor++;
            }
      }
      return sonars;
}

int myRobot::getX()
{
      return -1 * robot.getY();
}

int myRobot::getY()
{
      return robot.getX();
}

int myRobot::connect()
{
      Aria::init();
      Aria::setKeyHandler(&keyHandler);

      robot.attachKeyHandler(&keyHandler);

      serConn.setPort();
      robot.setDeviceConnection(&serConn);

      robot.addRangeDevice(&sonar);

      if (!robot.blockingConnect())
      {
            printf("Could not connect to robot... exiting\n");
```

```
            Aria::shutdown();
            return 1;
      }

      // turn on the motors, turn off amigobot sounds
      robot.comInt(ArCommands::ENABLE, 1);
      robot.comInt(ArCommands::SOUNDTOG, 0);
      robot.comInt(ArCommands::SONAR, 1);

      // start the robot running, true so that if we lose connection the run stops
      robot.runAsync(true);
      return 0;
}

bool myRobot::turnDone(void)
{
      return robot.isHeadingDone();
}

bool myRobot::moveDone(void)
{
      return robot.isMoveDone();
}

void myRobot::stop(void)
{
      robot.setVel(0);
      robot.setRotVel(0);
}

bool myRobot::checkFront(void)
{
      int range;

      for(int x=0;x<=5;x++)
      {
            range = robot.getSonarRange(x);
            if(range < minDistance)
```

```
                return true;
        }
        return false;
}

int myRobot::disconnect(void)
{
          robot.setVel(0);                  // Stop the robot
          Aria::shutdown();                 // Shutdown Aria
          robot.disconnect();               // Disconnect from the robot
          return 0;
}

bool myRobot::isConnected(void)
{
        return robot.isConnected();         //returns true if the robot is connected
}
:
```

Appendix A.4 MyRobot.h

```
// myRobot.h: interface for the myRobot class.
//
//////////////////////////////////////////////////////////////////////

#if !defined(AFX_MYROBOT_H__CB03EFE0_5F0F_11D7_9B52_00E0988A2243__INCLUDED_)
#define AFX_MYROBOT_H__CB03EFE0_5F0F_11D7_9B52_00E0988A2243__INCLUDED_

#if _MSC_VER > 1000
#pragma once
#endif // _MSC_VER > 1000

class myRobot
{
public:
	myRobot();		//constructor
	virtual ~myRobot();		//deconstructor

	void move(int distance);	//moves the robot forward if distance > 0 and backwards if distance < 0

	void rotate(int theta);	//rotates the robot counter-clockwise for theta > 0 and clockwise for
theta < 0

	double ** scan(void);		//using the center of the robot as the relative position,
				//returns and array of x,y coordinates of the detected object
				//and the distance the sonar was from the object

	int connect(void);		//connects to the robot

	int disconnect(void);		//disconnects from the robot

	bool turnDone(void);		//returns true if the robot is done turning

	bool moveDone(void);		//returns true if the robot is done moving

	void stop(void);	//Stops the robot from moving and turning
```

```
	bool checkFront(void);		//returns true if there is something infront of the robot
	int getX(void);			//returns the X-position of the robot where the front of the robot is
north
	int getY(void);			//returns the y-position of the robot where the front of the robot is
north
	bool isConnected(void);		//returns true if the robot is currently connected
};

#endif // !defined(AFX_MYROBOT_H__CB03EFE0_5F0F_11D7_9B52_00E0988A2243__INCLUDED_)
```